EFFECT OF THE MAGNETIC FIELD ON THE DIRECTIONAL BEHAVIOR OF GOLDFISH

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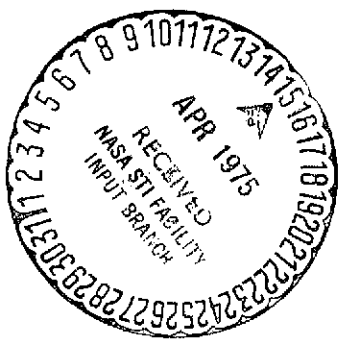

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16. Abstract

Several fish are able to perceive the earth magnetic field and use it as a direction finder. An artificially reduced field had a similar effect. They follow the magnetic field when in a quiescent state and when shocked. Studies have not yet shown the source of these perceptive and reactive mechanisms and the causes for changes in directional behavior of organisms.

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G. Becker

Goldfish (Carassius carassius auratus), in their /1* quiescent behavior, frequently take on a position over a prolonged period of time in which their body axis lines up in the N/S- (S/N-) or E/W- (W/E-) direction. This observation was confirmed in fish 5 to 8 cm long kept individually in cylindrical glass containers 10 to 12 cm in diameter. The glasses, mostly to avoid mirror effects, were covered both on the inside and the outside with white paper. The preferential position along one of the four primary orientations of the magnetic field, for example in a 27°C air-conditioned room in the cellar in which the magnetic field directions and intensities were known, was unmistakeable. Even the 45° angle with respect to the primary direction was chosen in the quiescent state with a certain frequency. Light effects were of no consequence; however, they could affect the direction of the head of the fish. The walls of the room form a 22° angle with the directions of the earth's magnetic field. Neon bulbs in the ceiling, which were used in most experiments, run parallel to the room orientation.

Without the swimming motion, fish appear to follow two behavioral states. In one of these, the animals follow a random direction and are rotated by the water motion; in the other, more active and "more alert," several fish are found to be oriented in the same direction or at a 90° angle thereto. Their preference lies with the major magnetic field directions, particularly if the fish are "shaken up" in the containers by means of knocking or a slight vibration. At that point, and seeking to escape, they spontaneously adopt a N/S, E/W,

* Numbers in the margins indicate pagination in the foreign text.

S/N, or W/E direction which they maintain for some time thereafter.

By compensating for the earth magnetic field, it was examined whether this field actually determines the orientation of the animals. For this purpose, they were kept in an air-conditioned room and individually in a glass at the center of a Helmholtz coil 1 m in diameter. This type of coil was first used to demonstrate the effect of the magnetic field on the orientation of flies [3]. Several insects are able to orient themselves according to the earth magnetic /2 field and under certain conditions they do so regularly [2]. Inside the coil, the fish were somewhat more restless and a 45° orientation was somewhat more frequent than elsewhere in the room. The orientation of the body axis in the northern, eastern, southern or western direction continued for a relatively long time and in most cases was quite accurate within approximately 5°. Compensation of the total magnetic field reduced the activity of the fish in motion somewhat. Orientation in given directions in the quiescent state and as a shock reaction ceased. Thus, the ability of these fish to perceive the earth's magnetic field and to use it as a direction finder has been demonstrated. If, following the compensation of the magnetic field, this field is then switched back to its normal strength, the quiescent fish begin to move after several seconds regardless of their previous orientation. However, it usually takes several minutes until they orient themselves in the N/S or E/W direction. The shock thus immediately orients them toward one of the magnetic field directions.

If the total earth magnetic field of 445 to 450 mOe is reduced to 220 mOe in a Helmholtz coil, the fish were still able to orient themselves according to the magnetic field. When this strength

was reduced to 110 mOe, they were no longer able to do so except several minutes after the switchover. The fish react to the field orientation of a ferromagnet which is considerably stronger than the earth magnetic field.

This report contains no quantitative orientation and time data to support the observations and conclusions. It is designed to awaken interest in the investigation of the orientation behavior of fish vis a vis magnetic fields, and with respect to other effects with greater accuracy. The fact that fish are able to react to magnetic fields within a range of 10 to 150 Oe was demonstrated by experiments and measurements of motor activity in trained animals [5]. The ability to perceive very slight differences in the electric field is also known [7]; therefore, it should be investigated whether the animals also orient themselves according to the electric field. Finally, observations made on fish schools which in the absence of other influences prefer the meridian orientation have led to the assumption that an orientation according to the earth's magnetic field is involved [8-10]. The author is not familiar with any experimental proof. In connection with the reactions to the training exercizes [5] it has since been shown that the perception of the magnetic field is not located on the sides of the fish, but evidently in the diencephalon [6].

The ability to orient themselves according to the magnetic fields has been demonstrated now for Protozoa, Turbellaria and mollusks [4, 1], various insects and all the way up to verterbrates. Investigations are still outstanding on the perception and reaction mechanisms and the causes for changes in directional behavior of organisms vis a vis the magnetic field of the earth.

For the compensation experiments, the facilities of the /3
Bundesanstalt für Materialprüfung [Federal Institute of Materials Testing] were used. Our thanks to Mr. H. Sander, M. A., Physics, for the measurement and calibration of the magnetic field values.

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